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'DUCTER'

Low Resistance
TESTING SET

PUBLICATION No. 269/1

INSTRUCTION BOOK

FOR USE WITH

Trade **DUCTER** Mark

LOW RESISTANCE TESTING SETS

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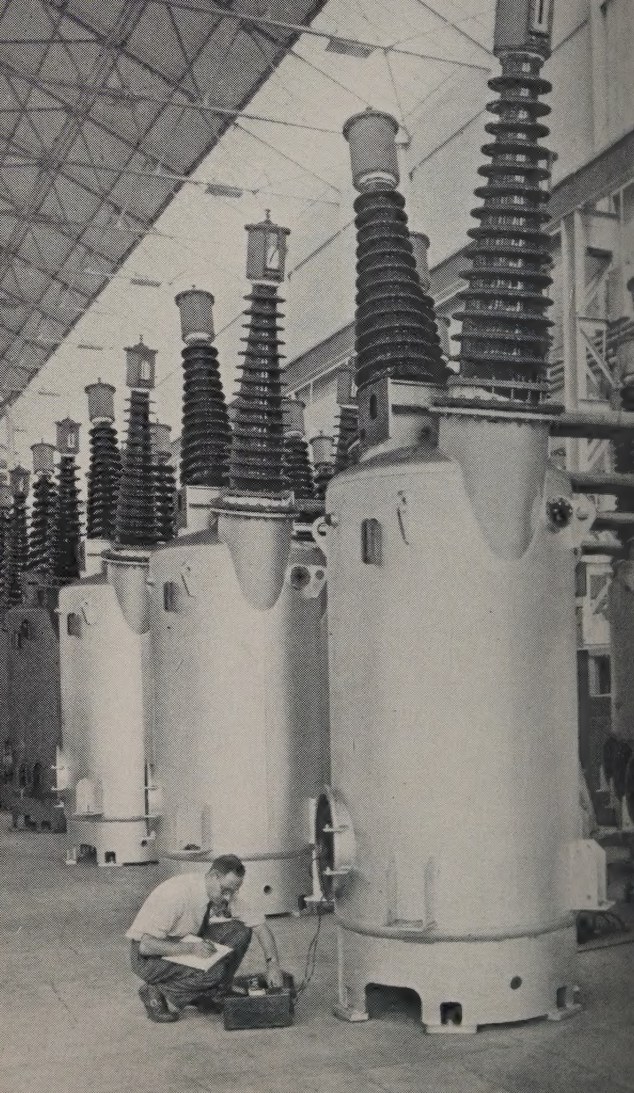

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igure 1. Using a Ducter Ohmmeter to measure the resistance cross the contacts of a BTH 132 kV 2,500 MVA oil circuit breaker.

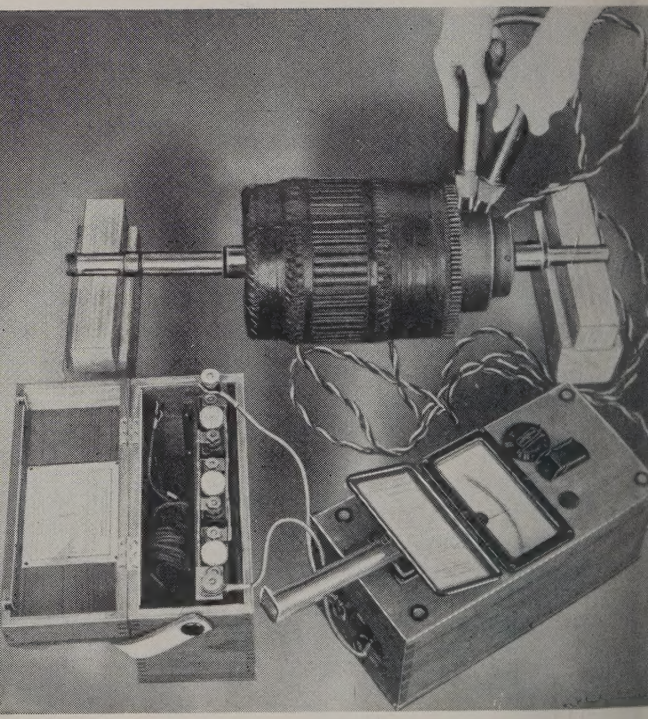


Figure 2. The Ducter Low Resistance Testing Set in use with Duplex handspikes. The battery case illustrated contains three alkaline cells and a compartment for the leads and test spikes.

INTRODUCTION

The Ducter Low Resistance Testing Set or Ducter Ohmmeter is a direct reading instrument for measuring low resistances from a few ohms down to 1 microhm. It embraces the same high quality workmanship and accuracy of reading which characterise the Megger series of insulation and continuity testers.

The following are some of the advantages of the Ducter Testing Set:—

1. *Direct reading.* No calculations are necessary other than the multiplying factor on the range switch.

2. *Accurate* to within one per cent. of the full scale reading.

3. *No adjustments* for battery voltage.

4. *Substantial current* is passed through the resistance under test.

5. *A Cut-out* is provided to protect the movement if an unexpectedly high resistance is encountered.

6. *Robust construction* suitable for shop or field use.

The Ducter Low Resistance Testing Set is especially useful for measuring the resistance of switch contacts, rail bonds, armature windings, transformer windings, copper bars, fuses, soldered joints, earth continuity conductors, etc. It is widely used by industrial concerns, railways, insurance companies, electricity supply authorities, and collieries, being particularly well adapted to carry out the tests required by the Coal Mines Act.

FACSIMILE SCALES

Figure 3
No. 37002

Figure 4
No. 37003

Figure 5
No. 37005

The ohmmeter

This is contained in a strong hardwood case measuring 16 in. × 7 in. × 8 in., the instrument weighing about 18 lbs. The case is provided with a carrying handle, range switch, cut-out and resetting switch, two terminals at one end for the battery and four at the other for the current and potential connections. The scale length is $4\frac{5}{16}$ in., each instrument being individually calibrated.

Ranges

There are three standard instruments, the facsimile scales of which are given opposite.

When using the lowest range of instrument No. 37002, where the current may be as high as 100 amperes, it is necessary to press a current switch situated in the top of the case (see Figure 7).

Cat. No.	Position of Range Switch	Value of Maximum Reading on Scale		Value of Each Division on Scale		Approx. Testing Current
	Multiply by	Microhms	Ohms	Microhms	Ohms	Amps.
37002	10,000	1,000,000	1.00	10,000	.01	1
	1,000	100,000	.10	1,000	.001	1
	100	10,000	.01	100	.0001	1
	10	1,000	.001	10	.00001	10
	1	100	.0001	1	.000001	100
37003	1,000	1,000,000	1.00	10,000	.01	1
	100	100,000	.10	1,000	.001	1
	10	10,000	.01	100	.0001	1
	1	1,000	.001	10	.00001	10
37005	Inner Scale	5,000,000	5.00	100,000	.1	.2
	1,000	500,000	.50	10,000	.01	1
	100	50,000	.05	1,000	.001	1
	10	5,000	.005	100	.0001	2
	1	500	.0005	10	.00001	15

The cut-out

An automatic cut-out is incorporated to prevent damage to the movement if an unexpectedly high resistance is encountered.

The battery

The cells are of the alkaline type, capable of a high rate of discharge.

For Catalogue No. 37002, the instrument of the lowest range, a single cell of 220 ampere-hour capacity is supplied capable of a very high rate of discharge. The maximum current taken from it on the lowest range is 100 amperes.

For Catalogue Nos. 37003 and 37005, the battery consists of three cells, each of 10 ampere-hour capacity, connected in parallel. They are housed in a strong wooden case having a separate compartment for leads and handspikes. The maximum current taken is 10 amperes by Catalogue No. 37003 and 15 amperes by Catalogue No. 37005.

The Ducter Testing Set should normally be used only with the battery supplied, but if used with other batteries these must not have a voltage higher than that furnished by one alkaline storage cell, approximately 1 volt, and be capable of giving the maximum current specified above. This will ensure the correct testing current.

If a number of resistances are connected in series and tested by the single handspike method as described on page 15, it may be necessary to use a battery having a higher e.m.f. so as to obtain the testing current.

Battery maintenance instructions are given on page 19.

Duplex handspikes

The instrument is provided with a pair of Duplex handspikes each containing two spikes, one for the current connection and the other for the potential connection. The spikes, which are normally held in the outward position by powerful springs, slide into the handle at the same time rotating when pressed against an object. Good contact with the conductor is thus secured, and the rotation ensures penetration through scale or dirt.

Duplex handspikes must not be used on the lowest range (multiply by 1) of instrument No. 37002, as they will not permit the full 100 amperes to flow.

Single handspikes

A pair of single handspikes is also provided. When using them the current terminals are connected by independent leads so that the current flows through the resistance under test. The handspikes are connected to the potential terminals and can be applied to any part of the circuit through which the current is flowing. The instrument then indicates the resistance between the points at which the handspikes are applied.

Current leads

The resistance of the current leads from the terminals CC is not included in the measurement. This resistance must, however, be sufficiently low to allow the full operating current to flow. The maximum current values are:—

Instrument No.	37002 ..	100 amperes
„ „	37003 ..	10 „
„ „	37005 ..	15 „

For instrument No. 37002 heavy current leads are required for the lowest range and the resistance of each must not exceed 0.0014 ohm per lead (0.0028 per pair). The leads should be fitted with clamps. Two leads, for example, each 6 ft. 6 in. long of 368×0.012, or 10 ft. long of 434×0.0148 would be suitable.

Potential leads

The potential (red) leads in the Duplex handspikes, and the leads in the single handspikes form part of the measuring circuit. They are accurately adjusted to a resistance of 0.02 ohms per lead (0.04 ohm per pair).

If other leads are substituted, it is important that they should have the correct resistance.

If, for any special reason, extra long leads are required having a resistance above the allowance of 0.04 ohm per pair, a correction factor will have to be applied to the instrument readings, and a table of these factors will be found on page 25. The resistance of the leads can be measured on the instrument.

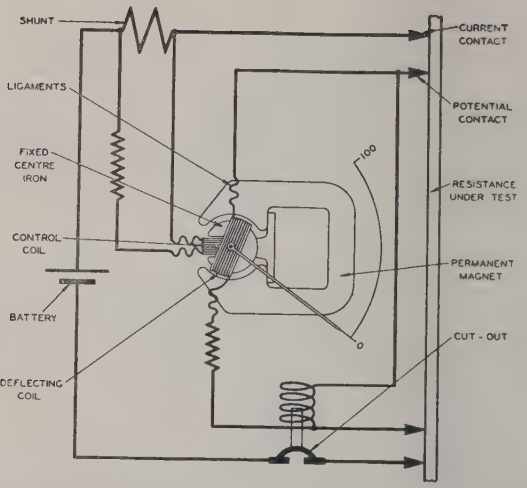


Figure 6. Simplified diagram of connections with the range switch omitted.

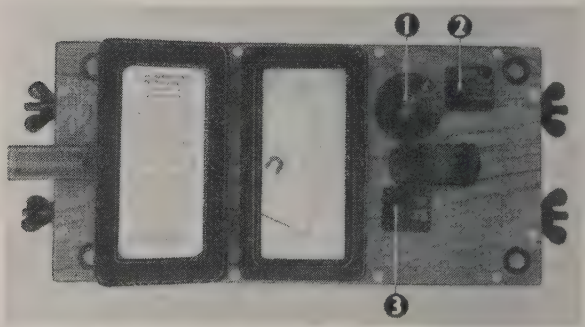


Figure 7. Plan view of Catalogue No. 37002 showing (1) range switch, (2) current switch for lowest range, (3) cut-out reset button.

PRINCIPLE OF OPERATION

The movement is of the permanent magnet moving coils type. The moving element consists of two coils rigidly secured at an angle to one another, and pivoted in spring mounted jewels so that the coils swing in the field of a permanent magnet.

Connections to the moving coils are made through thin ligaments exercising inappreciable control.

The control coil is connected across a shunt in the main circuit and the current in this coil is therefore proportional to the current in the resistance under test. The deflecting coil is connected across the resistance under test, and carries a current proportional to the potential drop.

The polarity of the two coils is so arranged that the torques developed oppose one another.

The position of the movement is therefore dependent on the ratio between the potential drop and the current, i.e. on the value of the resistance being measured. The scale is calibrated directly in ohms or microhms.

The instrument being a true ohmmeter, its accuracy is unaffected by variation in battery voltage, and no adjustment is required, the instrument being always ready for use.

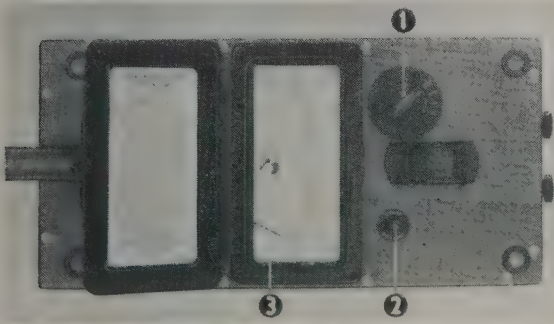


Figure 8. Plan view of Catalogue No. 37003 showing (1) range switch, (2) cut-out reset button, (3) cut-out indicator, open.

Figure 9. Measuring the resistance in each phase of a BTH 33 kV., 750 MVA oil circuit breaker.

HOW TO MAKE TESTS

Caution. Do not test apparatus which is "alive."

General

Stand the instrument on a fairly level base with the battery terminals to the left. Avoid placing it on large masses of iron, or in a strong magnetic field.

Connect the battery to the positive and negative terminals. If the battery is wrongly connected the pointer will read below zero when the test connections are made. As the movement has no control spring, the pointer will not take up a definite position until the test connections are made.

Range switch

Unless the approximate value of the resistance under test is already known, when the appropriate range can be chosen to start with, commence a test with the range switch set for the highest range (highest multiplier or Inner Scale). If the reading is less than one-tenth of the full scale, set the range switch for a lower range. If it is still less than one-tenth of full scale set the switch for a still lower range.

If the wrong range has been selected and the points of the cut-out indicator are seen to separate, change to a higher range and reset the cut-out by pressing the appropriate button on the top of the instrument. (See Figures 7 and 8.)

After a test return the switch to the "Off" position. This is important when using the single handspike method of test, so as to avoid running down the battery.

Recording results

To avoid mistakes, record the reading on the scale and the position of the range switch separately. The actual resistance in ohms or microhms may then be entered in another column.

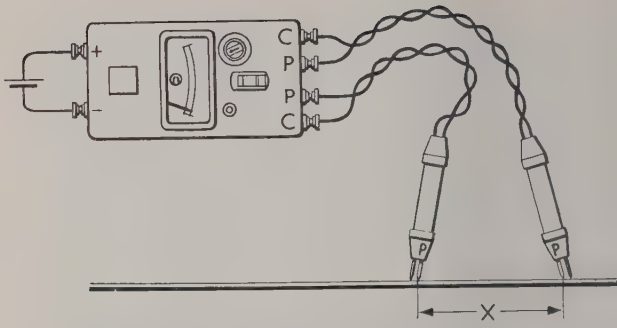


Figure 10. Test with Duplex handspikes. The potential spikes PP are in the path of the current and the resistance measured (X) is that between the two potential spikes.

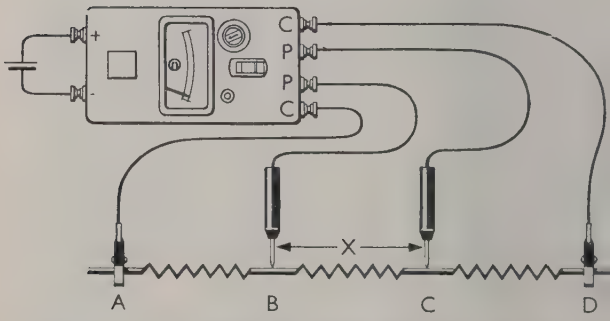


Figure 11. Test with single handspikes. The current leads are clamped on at A and D and the potential spikes applied to A and B, B and C, and C and D. The resistance measured is that between the potential spikes.

Testing with Duplex handspikes

Connect the black leads of the Duplex handspikes to the current terminals (CC) and the red leads to the potential terminals (PP).

Apply the Duplex handspikes to the resistance which is to be measured, forcing the handles down the spikes as far as they will go. The current passes through the conductor under test from one current spike to the other, and the potential spikes must make contact with the conductor in the path of the current. The potential spikes are distinguished by the letter "P" marked on the handles. When the resistance has terminal pieces of negligible resistance, this precaution may be ignored. The actual resistance measured is that between the two potential spikes, i.e., over the distance "X" in Figure 10.

Caution. Duplex handspikes must not be used on the lowest range (multiply by 1) of instrument No. 37002, as they will not permit the full 100 amperes to flow.

Testing with single handspikes

When using single handspikes the current terminals are connected by independent leads to the resistance under test, and the single handspikes are applied to any part of the circuit through which current is flowing.

When separate current leads are used, the pointer will move to zero until the potential spikes are applied. With the potential leads crossed, the instrument will read below zero.

Return the switch to the "Off" position after testing.

The single handspike method *must* be used on the lowest range (multiply by 1) of instrument No. 37002, and heavy current leads are necessary in order to pass the 100 ampere test current. These leads must have a resistance not exceeding .0014 ohm per lead (see under Current leads on page 9). On this range also the current switch situated on the top of the instrument must be pressed when testing.

When testing a number of resistances in series with single handspikes, it may be necessary to increase the voltage in order to obtain the required testing current.

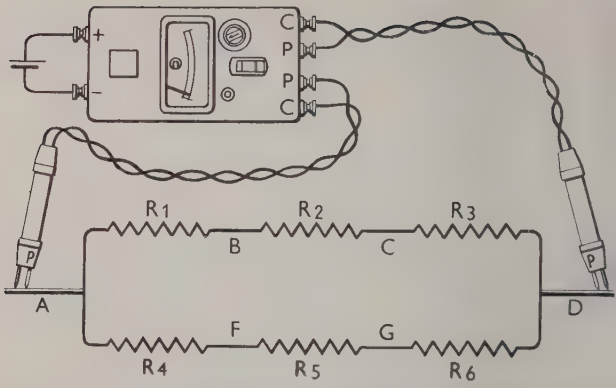


Figure 12. Testing resistances in parallel with Duplex handspikes.

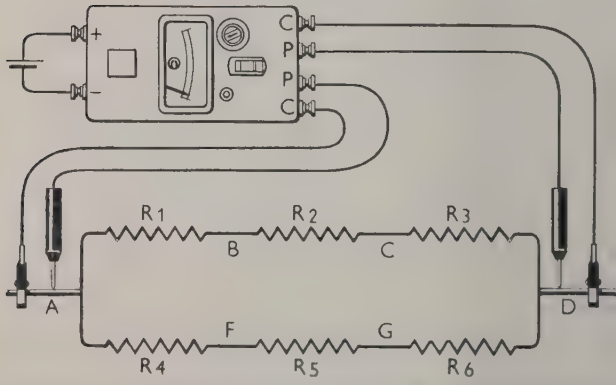


Figure 13. Testing resistances in parallel with single handspikes.

Testing resistances in parallel

With both current and potential connections connected at A and D (Figures 12 and 13) the instrument will read the combined resistance of the two parallel circuits, e.g.,

$$R=\frac{(R_1+R_2+R_3)\times(R_4+R_5+R_6)}{(R_1+R_2+R_3)+(R_4+R_5+R_6)}$$

Testing between A and B, B and C or C and D will, however, only give a comparison of the resistance R_1, R_2 and R_3 and not the true value of each resistance.

For instance when using Duplex handspikes, a test between B and C (Figure 12) will give the value of resistance R_2 in parallel with resistances R_1, R_3, R_4, R_5 and R_6, and the reading will thus be less than the true value of R_2.

With the single handspikes, although the resistances R_1, R_2 and R_3 (Figures 13 and 14) can be compared by moving the potential spikes between A and B, B and C and C and D, their true value will not be given because the whole of the testing current is not passing through the resistance under test. For instance, if the two parallel circuits are of equal resistance, only half of the battery current will pass through each circuit so that the resistance readings on the components of each circuit will have to be multiplied by two, or by three if there are three parallel circuits of equal resistance.

A few formulae for calculating the resistances of individual components of a network are given on page 27.

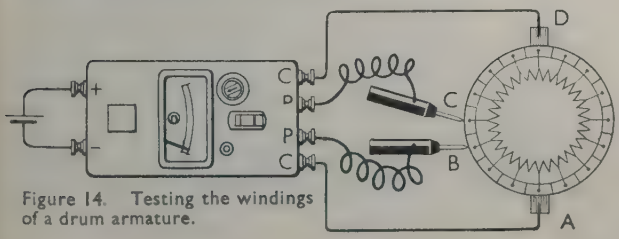


Figure 14. Testing the windings of a drum armature.

Testing highly inductive circuits

When testing highly inductive circuits such as the windings of large transformers, the pointer will, at first, move to full scale reading gradually creeping back to a steady value. This phenomenon is due to the time constant of the circuit, and it may be a few seconds before a reading can be taken.

Caution. With highly inductive circuits it is advisable to remove the potential spikes *before* breaking the current circuit so as to prevent a high induced voltage across the potential circuit of the instrument.

Figure 15. Measuring the resistance of the low voltage winding of a 33,000 400 volt 100 kVA transformer. Gresham Transformers Ltd.

BATTERY MAINTENANCE

As explained earlier in the text, Catalogue No. 37002 Ducter Low Resistance Tester is supplied with a single Alklum cell type GK22H of 220 ampere-hour capacity, whilst Catalogue Nos. 37003 and 37005 are supplied with a battery containing three Nife cells type SS.7 connected in parallel and having a total capacity of 30 ampere-hours.

The following general instructions should be followed, and further details are also given in the maker's instructions issued with the batteries.

CAUTION

1. Lead battery acid or even slightly acidulated water will ruin the cells. Utensils or hydrometers which have been used with acid batteries must not be used.
2. Do not examine the cells with a naked light or cause sparks by breaking connections with the current flowing, as the gases evolved are explosive.
3. Use care as the electrolyte will burn the skin or clothing. Treat burns immediately with boracic acid powder or solution.
4. Keep cells clean and dry as dirt and damp cause leakage current. The metal cases of the cells form the positive electrode; do not therefore lay tools on the battery, and when replacing the leads in the battery box take care that the tags at the ends of the leads do not touch the battery.
5. In no circumstances must the temperature of the cells be allowed to rise above 115° F. (46° C.).
6. Batteries must not be operated with the level of the solution below the tops of the plates. A cell must never be emptied of electrolyte unless it is in a fully discharged condition.

Delivery

Cells or batteries may be delivered filled with electrolyte or empty, when the solid electrolyte will be found in a separate container. Those supplied filled are in a fully charged condition.

Batteries supplied empty must be filled and prepared immediately as described in Sections 8 and 9.

Cells and Batteries Delivered Filled and Charged

1. Preparation for use

Remove the solid plugs from the filler openings and fit the vented plugs or close the vent caps. The solid plugs should be retained for future use. Vented plugs and vent caps must remain fitted at all times, even during charging, and should only be removed when topping up, otherwise carbon dioxide in the air will damage the cells.

Cells supplied fully charged will then be ready for use.

2. Topping up

Batteries must not be operated with the level of electrolyte below the tops of the plates. The correct depth of electrolyte above the top of the plates is:—

Alklum cell type GK.22H .. $1\frac{1}{2}$ ins.
Nife cells type SS.7 .. .. $\frac{3}{4}$ in.

Make good evaporation by adding pure distilled water, never by adding electrolyte.

Top up with distilled water before charging and test the specific gravity at least one hour after the end of a charge. The specific gravity should be within the limits of 1.160 to 1.220 at 60° F. (15° C.).

3. Discharging

The normal rate of discharge is as follows:

Alklum type GK.22H .. 22 amperes for 10 hours
Nife battery of three SS.7 cells connected in parallel } 3 amperes for 10 hours

Widely different rates can be employed provided the temperature does not exceed 115° F. (46° C.).

The normal voltage is 1.2 volts per cell, and the cells are fully discharged when the voltage falls to about 1.10 volts per cell when discharging at the normal rate.

Over discharge will shorten the life of the battery.

4. Routine charging

The voltage required for charging is 1.4 volts rising to 1.7 volts after 7-hour charging period.

The normal full charge is as follows:—

Alklum Cell type GK.22H .. 44 amperes for 7 hours

Nife battery of three cells type SS.7 connected in parallel } 6 amperes for 7 hours

A normal charge can always be given and a fully discharged battery must always be given a full normal charge before being used again.

Lower or higher rates can always be employed provided the time of charge is varied accordingly and the temperature does not exceed 115° F. (46° C.). Keep the vented stoppers in place and the vent caps closed during charging.

Specific gravity and gassing are no indication of the state of charge which must be controlled on a current-time basis.

5. Renewing electrolyte

Renew the electrolyte every two years or sooner if the specific gravity falls to 1.160. Proceed as follows:—

First prepare the renewal solution. See Section 7.

Completely discharge the battery at the normal rate to 0.80 volts per cell.

Pour out the old electrolyte. Do not shake the cells when emptying and do not wash them out with water or old electrolyte.

Drain for 15-30 minutes, no longer.

Pour in the new electrolyte to exactly the correct level above the plates.

Charge the battery at the normal rate for 15 hours and then allow to stand for one hour and check the specific gravity (see Section 2).

6. Storage

Fully charge the battery at the normal rate for seven hours and then discharge it at the normal rate for five hours. Fit the solid plugs.

Before returning to service, refit the vented plugs and give a full normal charge for 15 hours.

Batteries should be filled and charged immediately. Proceed as follows:—

7. Mixing electrolyte

Use only containers of clean plain iron, glazed earthenware, vitreous enamelled iron or ebonite. On no account use galvanised, painted, copper and aluminium vessels, or vessels with soldered joints.

When the mixing vessel is ready and clean, pour in pure distilled water in the proportion of 1 gallon (10 lb.) of water to each 4 lb. of solid electrolyte to be dissolved, and then carefully add the whole contents of a drum.

Note.—The electrolyte is a mixture of chemical compounds and unless the whole contents of a drum are dissolved the solution may not contain the correct proportion of constituents. Use type "3" electrolyte for cells GK.22H and type "R" electrolyte for cells 557.

Stir thoroughly with a plain iron rod, or clean unpainted stick until completely dissolved, cover to keep out air as much as possible and allow to stand until cooled to atmospheric temperature.

Remove scum, measure temperature and adjust specific gravity carefully by adding small quantities of distilled water and thoroughly stirring until this is at the correct figure, namely:—

Temperature	*For first filling*	*For renewal*
60° F. (15° C.) ..	.. 1.210 ..	.. 1.230
80° F. (27° C.) ..	.. 1.205 ..	.. 1.225
100° F. (38° C.) ..	.. 1.200 ..	.. 1.220

8. Filling the cells

Remove the solid plugs from the cells, one at a time and pour in the electrolyte using a glass or glazed earthenware funnel, until the level above the top of the plates is:

Alklum type GK.22H .. .. $1\frac{1}{2}$ ins.
Nife cells type SS.7 .. .. $\frac{3}{4}$ in.

Immediately put in the vented stoppers or close the vent caps. Keep the solid stoppers as they may be required

later. Keep the surplus mixed electrolyte in a glass stoppered bottle.

Allow the cells to stand for 24 hours after filling and before the first charge, and if need be add a little of the surplus electrolyte to bring up to the correct level.

9. Initial charges and discharges

(a) First cycle.

Alklum type GK.22H charge at 44 amperes for 15 hours; discharge at 22 amperes for 5 hours.

Nife battery of 3 cells SS.7, connected in parallel, charge at 6 amperes for 15 hours; discharge at 3 amperes for 5 hours.

Top up with distilled water to the correct level.

(b) Second cycle.

Repeat first cycle as above. Top up with distilled water to the correct level. Cells must not be discharged beyond 50 per cent. of rated capacity during the first and second cycles.

(c) Third cycle.

Charge at normal charge rate for 15 hours.

Discharge at the 10 hour rate till the voltage falls to 1.10 volts per cell.

(d) Final charge.

Charge at normal rate for 15 hours. Top up with distilled water to the correct level.

In all cases see that the temperature does not exceed 115° F. (46° C.).

Clean tops of cells, smear with Vaseline jelly. The battery is then ready for service.

CAUTION. To avoid damage from spilt electrolyte, the solid vent plugs should always be fitted before batteries are despatched by road or rail.

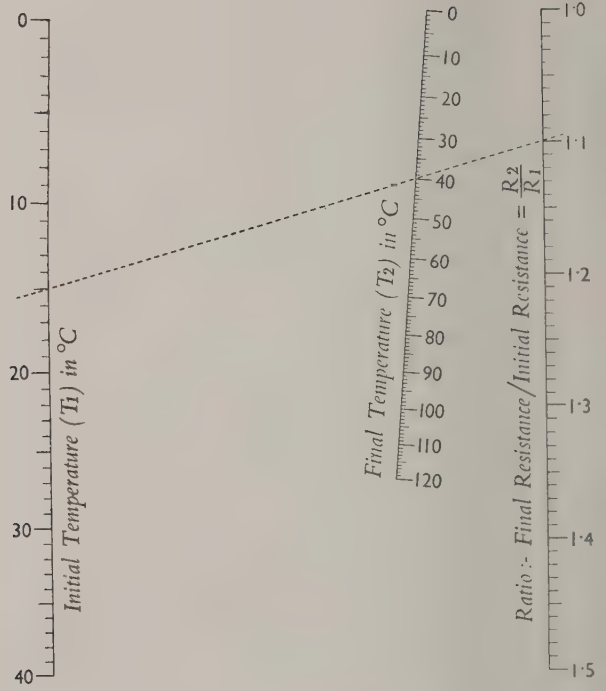


Figure 16.

Nomogram for estimating temperature by the change of resistance method, the metal being high-conductivity copper.
Example : If the initial temperature $T_1 = 15$ C and the ratio of resistance $\frac{R_2}{R_1} = 1.1$, then a straight-edge will show that the final temperature $T_2 = 40$°C.

Correction factor for long potential leads

The potential leads and spikes provided have a total resistance per pair of 0.04 ohm. For leads of higher resistance, multiply the readings by the correction factors given in the following table:

Cat. No.	Range		ohms per pair of leads			
			.06	.08	.10	.12
	microhms	ohms	Correction factors			
37002	1,000,000	1.0	1.0004	1.0008	1.0012	1.0016
	100,000	.1	1.004	1.008	1.012	1.016
	10,000	.01	1.04	1.08	1.12	1.16
	1,000	.001	1.04	1.08	1.12	1.16
	100	.0001	1.04	1.08	1.12	1.16
37003	1,000,000	1.0	1.0004	1.0008	1.0012	1.0016
	100,000	.1	1.004	1.008	1.012	1.016
	10,000	.01	1.04	1.08	1.12	1.16
	1,000	.001	1.04	1.08	1.12	1.16
37005	5,000,000	5.0	1.0008	1.0016	1.0024	1.0032
	500,000	.5	1.0008	1.0016	1.0024	1.0032
	50,000	.05	1.008	1.016	1.024	1.032
	5,000	.005	1.04	1.08	1.12	1.16
	500	.0005	1.04	1.08	1.12	1.16

Determining temperature by resistance tests

The Ducter Low Resistance Testing Set is often used for determining the average temperature of electrical equipment by measuring the resistance of certain conductors within that equipment. For high conductivity copper the temperature can be obtained from the nomogram on page 24, or by using the following formula:

$$T_2 = \frac{R_2}{R_1}(234.5 + T_1) - 234.5$$

Where T_2 = temperature in °C. at the time of test.

R_2 = resistance at time of test.

R_1 = known resistance at a temperature T_1.

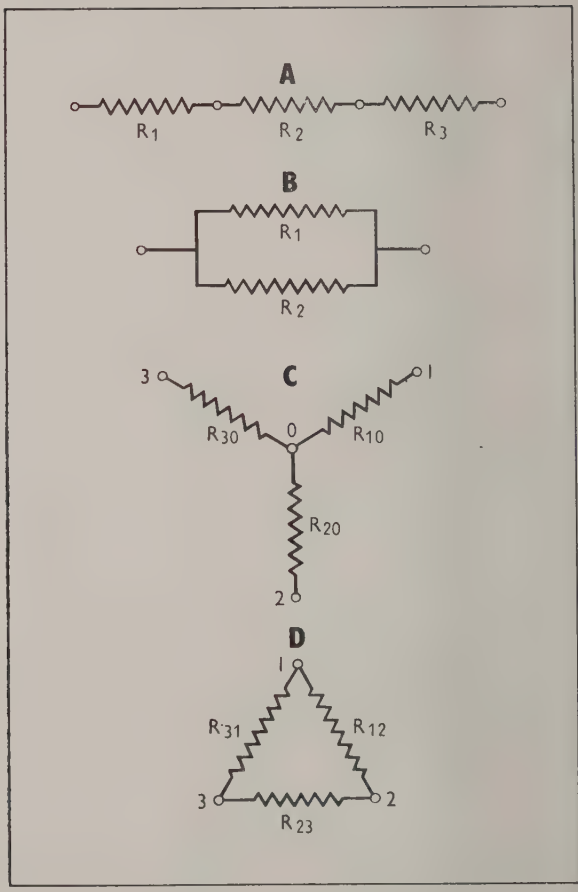


Figure 17. Resistance networks.

Resistance network calculations

(A) *Series networks*

$$\text{Total } R = R_1 + R_2 + R_3 + \ldots R_n$$

(B) *Parallel networks*

$$\frac{1}{\text{Total } R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \frac{1}{R_n}$$

Whence Total R for two paths $= \dfrac{R_1 R_2}{R_1 + R_2}$

Total R for three paths $= \dfrac{R_1 R_2 R_3}{R_1 R_2 + R_2 R_3 + R_3 R_1}$

(C) *Star networks*

$$R_{10} = \frac{R_{12} - R_{23} + R_{31}}{2}$$

$$R_{20} = \frac{R_{12} + R_{23} - R_{31}}{2}$$

$$R_{30} = \frac{R_{31} - R_{12} + R_{23}}{2}$$

(D) *Delta networks*

M = measurement between two terminals of the closed delta network.

$$R_{12} = \frac{N}{2M_{31} + 2M_{23} - 2M_{12}}$$

$$R_{23} = \frac{N}{2M_{31} + 2M_{12} - 2M_{23}}$$

$$R_{31} = \frac{N}{2M_{12} + 2M_{23} - 2M_{31}}$$

Where the numerator $N = 2M_{12}M_{23} + 2M_{23}M_{31} + 2M_{31}M_{12} - [(M_{12})^2 + (M_{23})^2 + (M_{31})^2]$

Figure 18. Testing switchgear at Longford Generating Station
British Electricity Authority.

SOME USES OF DUCTER INSTRUMENTS

To help owners of Ducter Low Resistance Testing Sets to make the fullest use of their instruments, we give in the following pages brief descriptions and extracts from letters we have received which illustrate the many purposes for which these useful instruments are employed.

British Electricity Authority (East Midlands Division)

(Extract from letter dated 2nd November, 1949)

". . . The instrument is used for the following tests:—

1. The checking of contact resistance between moving and fixed contacts of 33,000 volt, 6,600 volt and 400 volt switchgear. A typical limiting figure for a 400 amp 33,000 volt switch would be 250 microhms. By comparison with previous records, an indication of the condition of the contacts may be obtained without visual inspection if necessary. The routine tests are made once per year per equipment.

2. Yearly routine testing of 400 volt induction motors from 28 b.h.p. up to 365 b.h.p. for winding balance. These readings are recorded and compared each year. In the event of a suspected motor fault, winding balance is first checked, the Ducter ohmmeter giving an excellent indication of the electrical condition of the motor, short of damaged insulation resistance.

3. Yearly tests on starters controlling the above motors; in these cases it has been found that the ohmmeter gives indication of any high resistance spots developing in the starter contacts or outgoing cables and connections which might give rise to 'two-phasing' at a later date.

The Ducter ohmmeter was purchased originally because, as far as is known, it was the only instrument of its type and range on the market, and it has become, together with the Megger Insulation Tester, a basic tool for the investigation of motor and starter faults.

The instrument has been in practically continuous use for the past six years, and has given every satisfaction, the only renewals being the leads to the hand spikes."

British Electrical Repairs Limited

(Extract from letter dated 10th March, 1950)

". . . We attach hereto a list of various tests we make. We have every confidence in such tests when made by our staff with your Ducter Ohmmeter.

1. Measurement of very low resistances common on windings of large A.C. and D.C. machines. This may consist of terminal to terminal tests, or coil terminal to coil terminal tests, or coil groups. Bar wound jobs, whether D.C. armatures or A.C. stators, are bar to bar tested.

2. Measurement of low resistances in transformer winding, particularly where the winding consists of a number of conductors in parallel. Comparisons between the resistivity of parallel paths are most informative.

3. Testing of armatures with equaliser rings or connections compared or measured. This test is made by connecting the 'current' leads to the equaliser rings and measuring the bar to bar P.D. at the commutator with the single handspikes. Any bad joints are revealed during this test on equalised armatures.

4. When testing for high resistance joints, for example, at commutator lugs, winding end connection clips or equaliser joints, the spike points are inserted on either side of the jointed sections. This particular test has been found very reliable in determining if soldered connections are 100 per cent. good.

5. Testing conductivity of commutator risers. By testing between comm. bars and the extreme ends of each of the comm. risers on any armature it is possible to detect cracks, faulty connection where the riser is connected to the comm. bar, or a combination of both faults which would ultimately give trouble in service. Indication of defect, of course, is given by a higher than normal resistance reading.

6. Bar wound rotors give trouble frequently due to breaks and defects in the bars. This can be located when abnormal high resistance measurements are obtained by measuring axially along the slot length.

7. Earth faults on machine windings can be located as follows. First check the resistance between the shaft (or spider) and equal spaced points on the winding. For armatures test at equal spaced comm. bars, and for A.C. windings on equal spaced stub, or if bar wound, end connections. Thus by observing the point of minimum resistance it is possible to locate earth fault with great accuracy."

Figure 19. Ducter test of traction armature. General Electric Co., Ltd.

Collins Electrical Limited

(Extract from letter dated 16th May, 1952)

"We are pleased to inform you that we originally purchased our instrument from you primarily for taking more accurate tests of large A.C. commutator motor armatures, of which we carry out a large number of repairs, as the normal millivolt test was not sensitive enough for these machines. We also use it on testing suspected faulty squirrel cage rotors for open circuits and cracks.

These are the two main uses to which we put the instrument although it is used on numerous other pieces of apparatus that come into the works for repair when we wish to obtain very sensitive readings."

Laurence, Scott & Electromotors Limited

(Extract from letter dated 24th October, 1950)

"We use it (the Ducter Ohmmeter) only for tests in the usual process of our manufacture of motors, generators, alternators, etc. For the sake of simplicity we append the procedure as carried out in these works.

All low resistance values are measured by the Ducter Ohmmeter at completion of winding. Armatures, series coils, interpole coils, wound rotors, stator windings, all induction regulator windings.

A check on all winding shop readings is made immediately completed machines arrive in test department with test department's own Ducter Ohmmeter.

At the end of all heat runs readings are again taken, to ascertain temperature rise by resistance method.

Thus, from the foregoing, it will be seen that the low resistance windings of each machine that is manufactured at these works is checked at least thrice before despatch, and each Ducter ohmmeter is in almost constant use.

We would state that we are extremely satisfied with the service and results given by these instruments."

Figure 20. Ducter test on the armature of a 275 h.p. motor under repair. Collins Electrical Ltd.

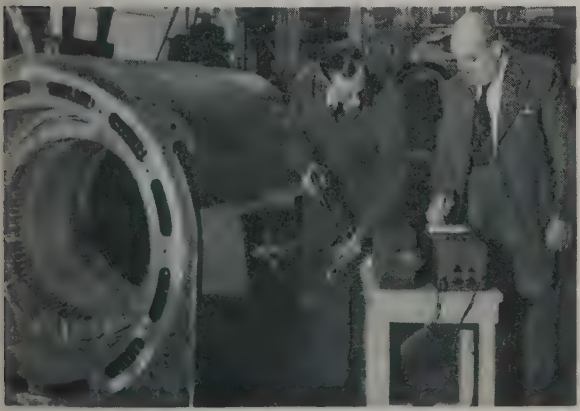


Figure 21. Resistance test of completed stator winding of squirrel cage motor. Laurence, Scott & Electromotors Ltd.

British Railways

A Ducter Ohmmeter has been in regular use at the Durnsford Road Electric Carriage Repair Shop, Wimbledon, of British Railways (Southern Region) since February, 1917. It is still in use for routine tests on traction motor armatures of both suburban and main line stock.

Southern Region electric trains are withdrawn from service every 12 to 18 months after running a distance of 100,000 miles in the case of suburban stock and 80,000 miles for main line stock.

After entering the repair shop, the bogies and motors are stripped down, thoroughly overhauled, re-assembled and tested before being returned to service.

Ducter Ohmmeter readings are taken of the resistance drop in the traction motor armatures, and if the readings are below a prescribed limit no further examination is considered necessary, but should they show wide diversions from the standard, a detailed examination is undertaken.

London Passenger Transport

(Extract from letter dated 28th November, 1949)

"(1) *Ducter Ohmmeter in department of Chief Mechanical Engineer (Road Services).* The instrument is used in the electrical test room at Charlton works for testing the ohmic resistance of trolleybus traction motor field and interpole coils, traction armatures, low-resistance blow-out coils and low resistance circuit breaker coils. It is in constant use and was selected because it is regarded as the most suitable type of equipment for the purpose.

(2) *Ducter Ohmmeters in Electrical Engineer's department.* Two instruments are in use:—

(a) The instrument in the substations section is most frequently used for checking the ohmic resistance of the numerous circuits in the windings of rotary converters after rewinding or repair. It is also used for locating faults in transformer windings.

(b) The instrument in the power stations is used in testing the resistance of the exciter armatures and fields, and the connections on high tension busbars and switchgear.

The frequency of use of these instruments is irregular, varying with the demand. They were chosen because of the speed with which measurements can be made and the reliability of the results."

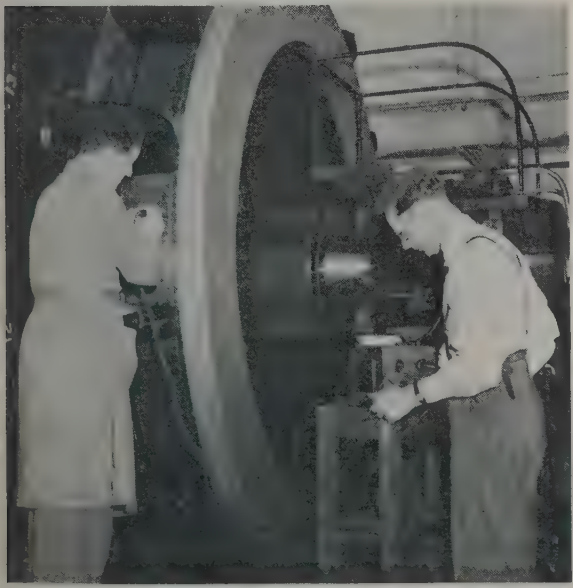


Figure 22. A Ducter Ohmmeter in use at the Jolimont Sub-Station of Victorian Railways, Australia. The railway organisation uses the instrument extensively for testing all types of contacts and joints, and the armatures of all rotating machines.

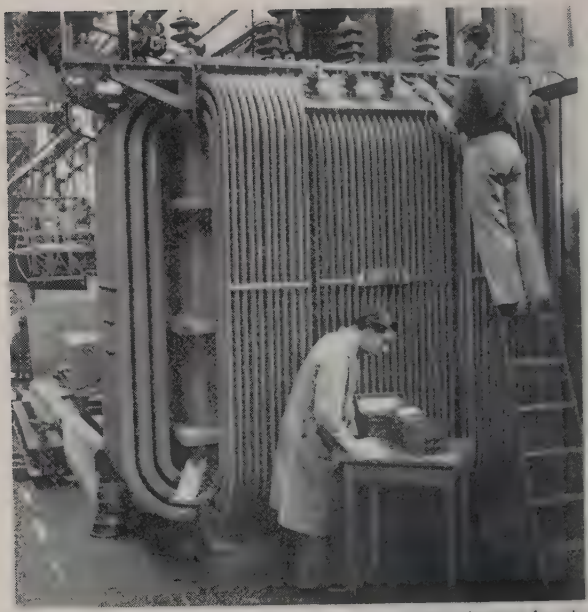


Figure 23. Testing a 2,500 kVA 3 phase Foster transformer for the Taranaki Electricity Power Board of New Zealand.

Foster Transformers Limited

(Extract from letter dated 2nd July, 1952)

"Our test room uses the Ducter Ohmmeter principally for measuring the resistance of transformer windings to determine their total copper losses, and their temperature rise by change of resistance after a heat run on full load. We have a model mounted, together with its associated battery, on a rubber tyred trolley which, due to the simple and robust design, enables measurements to be made very quickly, and proves the Ducter Ohmmeter a valuable help in routine transformer testing."

London Transformer Products Limited

(Extract from letter dated 29th May, 1952)

". . . we purchased two of these instruments about five years ago, and have since used them for the measurement of resistances of transformer windings up to the maximum value covered by the particular models we have. We have found them quite satisfactory for this purpose, and in view of their being portable it has saved trouble of bringing units into the test department for resistances to be measured."

Mersey Docks and Harbour Board

(Extract from letter dated 11th August, 1952)

". . . the Ducter Ohmmeter was purchased for use on three post-war diesel electric grab hopper dredgers. These vessels have an electrical system known as controlled constant current, the generators, propulsion motors, grab crane motors and winch motors all being in a series loop with a constant current of 750 amperes. The elimination of any generator or motor not required is accomplished by disconnecting the field and short circuiting the armature.

The amount of current passing through a stationary armature is determined by the resistance of the short circuiting contactor and armature circuit, a low contactor resistance ensuring that a minimum current passes through a stationary armature. The Ducter Ohmmeter is used each week to check the contactor circuit resistance, and it provides, in addition, the most convenient method for the routine testing of other portions of the constant current loop.

The Ducter Ohmmeter is used also for testing petroleum tank and pipe line bonds. There are inherent dangers of static discharges due to the flow of petroleum spirit, especially when contaminents are present, in pipe lines with flexible pipe joints. Efficient bonding and earthing are considered essential and the Ducter Ohmmeter has been found most convenient for testing the resistance of numerous pipe line and tank bonds."

Insurance Engineers Limited

(Extract from letter dated 22nd October, 1949)

". . . the Ducter Ohmmeter has been used for tests as required by Statutory Rules and Orders 1938 No. 1233, to measure the resistance of the earthing conductor. These tests have to be made every six months and recorded in the book Form 125. The Ducter Ohmmeter was chosen for this work, being a direct reading instrument and it was considered that it was the most suitable instrument for this work as numerous very low resistances have to be measured."

The Associated Portland Cement Manufacturers Limited

(Extract from letter dated 28th November, 1949)

"1. Our Ducter instruments are used—

(a) For the purpose of carrying out the statutory tests of line conductor and earth return path conductances in our quarries.

(b) For similar tests at our works although there is no comparable legal obligation in this case.

(c) For measuring the resistances of the windings of transformers, motors, etc., when commissioning after rewinding or when investigating faults.

(d) For determining the progression of resistance stepping when commissioning, or investigating faults in, starter or controller resistance banks.

(e) For 'drop' tests and copper temperature rise tests.

2. These tests are carried out every six months in the case of (a) and as the situation requires in other cases.

Your Ducter is the most suitable instrument which we have found to meet our requirements up to the 5 ohm limit."

The National Coal Board

The National Coal Board uses Ducter Ohmmeters for carrying out statutory tests of electrical plant as laid down in the Coal Mines Act. The instrument is found particularly valuable for testing the resistance of the armouring of cables and comparing it with that of the core.

Figure 24. Testing the resistance of earth and line conductors to a motor at a gravel screening plant. Insurance Engineers Ltd.

Figure 25. Test of trailing cable connections on an excavator. Associated Portland Cement Manufacturers Ltd.

Stewarts and Lloyds Limited

(Extract from letter dated 15th July, 1952)

"The testing of electrodes for specific resistance is now being made into a routine check and any abnormal resistances noted. Four measurements are made on each end, and a mean figure taken. Sometimes a variation of resistance along the length of an electrode is suspected, and because of the local nature of the measurement, this type of test is easily performed. (For this test the four prods are pressed against the side of the electrode.) The Ducter Ohmmeter enables the resistance of an electrode to be measured over a small area with ease and rapidity, and without damaging the electrode."

Colvilles Ltd.

(Extract from letter dated 1st August, 1952)

"We find the Ducter Ohmmeter invaluable in the Winding Department of our Repair Shop for the detection of high resistance joints and short circuits in the D.C. motors and generators of our large reversing mill equipment.

We have found that the sensitivity of the instrument is such that a deteriorating soldered commutator connection is shown up clearly and can consequently be attended to before a complete open circuit develops which might involve a major delay with loss of production.

The type of faults for the detection of which we use the Ducter Ohmmeter include shorted coils; unbalanced phases and shorted phases in A.C. machines; and in D.C. machines carbon shorts in commutators; shorted armature coils and faulty and open circuited armature joints."

Dorman & Smith Ltd.

(Extract from letter dated 8th August, 1952)

"Our Ducter Ohmmeter is treated as a Sub-Standard instrument, i.e. it is used whenever it is required to determine a low resistance with accuracy."

Figure 26. Measuring the specific resistance of a graphite electric furnace electrode. Stewarts & Lloyds Ltd.

Yorkshire Switchgear & Engineering Co., Ltd.

(Extract from letter dated 13th August, 1952)

"For 10 years we have standardised upon a Ducter test as the basis of our acceptance or rejection of all switchgear contacts and bolted joints. It has been our practice during this period to apply heat run tests to all prototype gear in order to establish compliance with BS.116 and at the conclusion of such tests we have made a careful check of the resistance of all contact points. The figures so obtained have then been used as the standard by which all production models of the prototype gear are compared after first establishing a safe figure of tolerance.

In our opinion this method of testing is equally as accurate as the accepted millivolt drop method and is far more readily applied to routine work.

Holden & Hunt Limited

(Extract from letter dated 6th June, 1952)

"Mainly, our Ducter Ohmmeter is used in connection with low voltage resistance welding machines, which have low resistance conductive paths to carry many thousands of amperes so far as the output is concerned, and up to one thousand, sometimes more, amperes at the input side, depending on the machine size and input voltage. These conductive paths, of copper usually, are, in actual fact, those of a normal alternating current transformer where the secondary resistance may be of the order of twenty to forty microhms (0.000020 to 0.000040 Ohm) and the primary resistance 5,000 to one million microhms (0.005 to 1 Ohm)

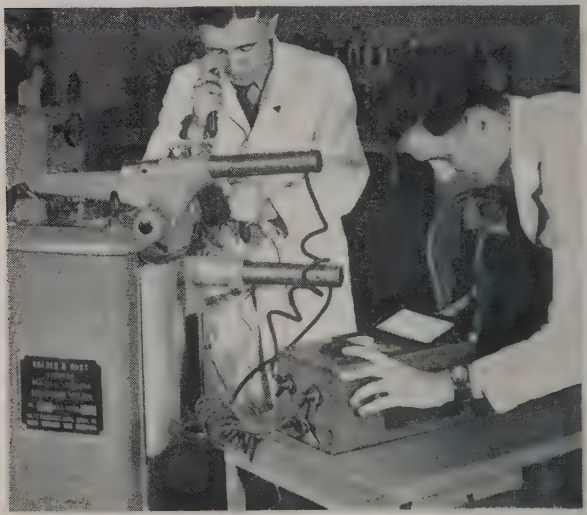


Figure 27. Testing a low-voltage resistance welder. Holden & Hunt Ltd.

again depending on machine size. The Ducter Ohmmeter covering this range adequately, is used for checking these resistances and splitting the total resistance in a circuit into its component parts, in joints, sectional area reductions, and change of material, etc. It is used very successfully during transformer temperature rise tests, particularly in connection with Canadian Standards Association approval, for obtaining average primary winding temperatures by the "Rise of Resistance" method.

The current circuit of the instrument is wired separately and the various resistance sections picked out by means of the single potential spikes, being careful, of course, to keep the spikes within the current entry points and along the line of flow.

The instrument has also been used frequently, with the dual spikes in this case, for checking secondary circuit cast components, prior to machining, for consistency of resistance and hence metal quality."

Johnson & Phillips Limited

(Extract from letter dated 27th October, 1950)

"The Ducter Ohmmeter is used in our switchgear department as a means for measuring contact and joint resistances on busbars and oil circuit breakers. During the type test the Ducter measurements are recorded and these are taken as standard for that particular type of unit. The ordinary production units are then tested with the Ducter instrument and a small tolerance allowed on the above standard measurements. We find that this is a very convenient way of comparing the contact resistances . . .

We find the instrument particularly useful in the measurement of contact resistances on our S.F. type of gear as the contacts on these units have to be individually set up and ground in.

We also use it for measurement of low resistances on the smaller sizes of transformer."

Figure 28. Testing a batch of H.R.C. fuses. E.M.P. Electric Ltd.

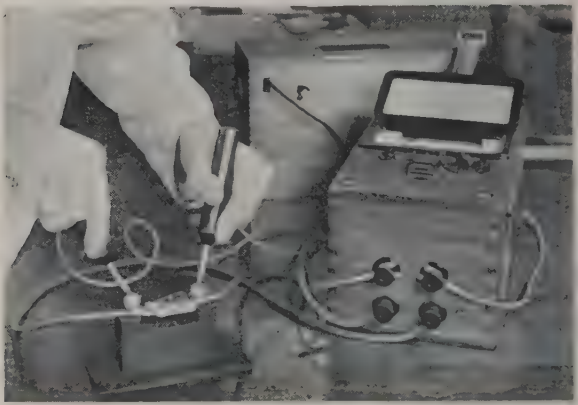


Figure 29. Measuring the resistance of a thermal cut-out. Hoover Ltd.

British Insulated Callender's Cables Limited

(Extract from letter dated 26th October, 1949)

"The two instruments supplied are both primarily used for the routine checking of the resistance of cartridge fuse-links to close tolerances. They are used in two forms:—

(a) Bench-mounted with contact points designed to facilitate the rapid testing of batches of the smaller types of fuse-links.

(b) With the hand-spikes provided by you for measuring the resistance of the larger fuse-links, and for switch contacts and joints.

They are in use for periods of several hours each day in conjunction with the bench-mounted fixture and intermittently for the other applications, and they were chosen for these purposes because of the direct indication in resistance units; and also because the multiple ranges enable a wide group of products to be tested.

The instruments have been found to be robust enough to withstand severe workshop practice, and transportable enough, with self-contained power supply, to be moved to the job when required, and at all times maintaining an accuracy sufficient for this exacting purpose.

We are very happy to express our satisfaction with regard to the instruments."

E.M.P. Electric Limited

The Ducter Ohmmeter is used for checking the consistency of quality in connection with high tension fuses.

For small fuses spikes are clamped vertically in a vice and the fuses pressed down to the points. For larger fuses normal testing methods are employed.

Hoover Ltd.

The Ducter Ohmmeter is used for measuring the resistance of bi-metal strips as used in thermal cut-outs and to check the circuit resistance of the complete welded assembly.

The British Celanese Limited

(Extract from letter dated 24th October, 1949)

"We would advise you that we use the Ducter Ohmmeter for routine tests in connection with the efficiency and joints in bus bar connections, i.e., to determine whether the joint has a small power loss at the rated load; to check if we have a low resistance across the contacts on heavy current carrying switchgear; the accurate determination of the resistance of short lengths of large cross-sectional area mains cable, and the resistance of ferrous and non-ferrous tubes of short length but having a very large cross-sectional area.

The instrument is used fairly frequently, and has given excellent accurate results. We chose this particular instrument because it was the only one to our knowledge available, which would give a value of resistance measurements from 1 microhm through the series of ranges up to 1 ohm."

Thames Board Mills Limited

(Extract from letter dated 5th June, 1952)

"The various uses to which we apply this instrument are as follows:

1. Testing for armature faults—on armatures of all sizes. Particularly is this valuable for the large armatures, such as on our turbo-generators, where other means of testing are not successful.

2. To establish the resistance values on remote ammeter leads, so that our ammeters may be so calibrated to give correct readings when installed in remote positions entailing rather long extension leads.

3. To check and ensure satisfactory surface contacts between bus-bars and connecting studs in our large type starters, which have been subjected to overheating due to burn-out of contactor contact tips."

Bowater's Lloyd Pulp and Paper Mills Limited

(Extract from letter dated 20th May, 1952)

"The principal use of the Ducter Ohmmeter is on the maintenance of our very extensive switchgear system: in fact the whole maintenance procedure is mainly based on the use of the Ducter instrument before and after maintenance inspections. Further, we carry out all our own switchgear erection here, and all busbar joints and connections are checked after erection by the Ducter Ohmmeter."

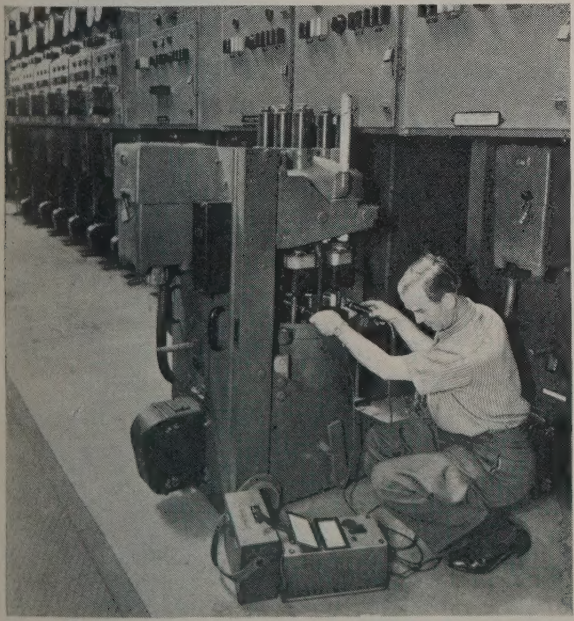
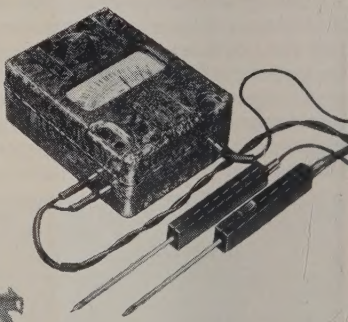
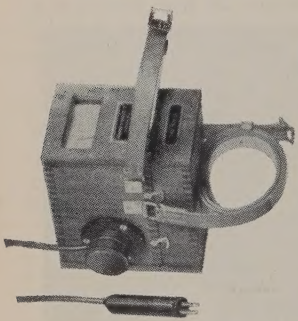


Figure 30. Testing contact resistance of 6.6 kV Ferguson, Pailin switchgear at Bowater's Lloyd Pulp and Paper Mills.

MEGGER OHMMETERS
FOR CONDUCTOR RESISTANCES

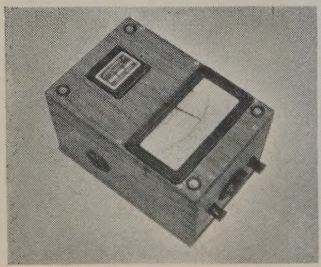
Megger Circuit Testing Ohmmeter with self contained battery. Ranges up to 200,000 ohms.

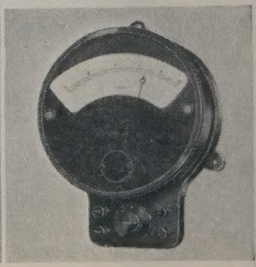




Megger Bond Tester with self contained battery. Range 0-0.1 ohms.

Megger Workshop Ohmmeters Bench and Switchboard types. Operated from external source of supply. Single and multi-ranges up to 1,000 ohms.





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